This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

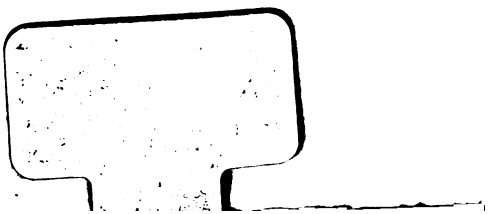
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

6000413280



1978. e. 3

+
301.

THE RADIOMETER,

AN INSTRUMENT WHICH REVOLVES CONTINUOUSLY UNDER THE INFLUENCE OF RADIATION.

Patent.

LONDON.

1876.

Price ONE SHILLING.

1978 e 3

THE RADIOMETER.

AN INSTRUMENT WHICH REVOLVES CONTINUOUSLY UNDER THE INFLUENCE OF RADIATION.

Patent.

LONDON.

1876.

Price ONE SHILLING.

Sold by JOHN BROWNING, 63, Strand, London.

BODLEIAN
21 9 1901
LIBRARY

PREFACE.

THIS Pamphlet contains a description of the construction, action, and uses of the Radiometer, which was discovered by Mr. Crookes, F.R.S., V.P.C.S., and first exhibited by him at the *Soirée* of the Royal Society, April 7, 1875. In order, however, that the action of the instrument may be more clearly understood, a brief account of the researches and experiments which led to the discovery of the Radiometer is first given.

THE RADIOMETER.

CHAPTER I.

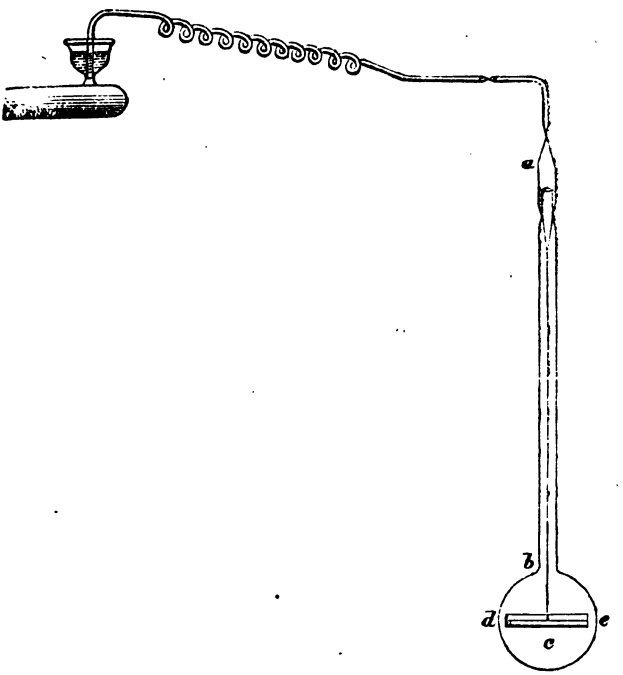
PRELIMINARY EXPERIMENTS.

MR. CROOKES'S researches were originally suggested by some observations made when weighing heavy pieces of glass apparatus in a chemical balance, enclosed in an iron case from which the air could be exhausted. When the substance weighed was of a temperature higher than that of the surrounding air and the weights, there appeared to be an interference with the force of gravitation. Experiments were thereupon instituted to render the action more sensible and to eliminate sources of error. These experiments led to the discovery that when radiation*

* See page 14.

falls on a light body delicately suspended in a vacuum it is driven away from the radiant source.

FIG. 1.



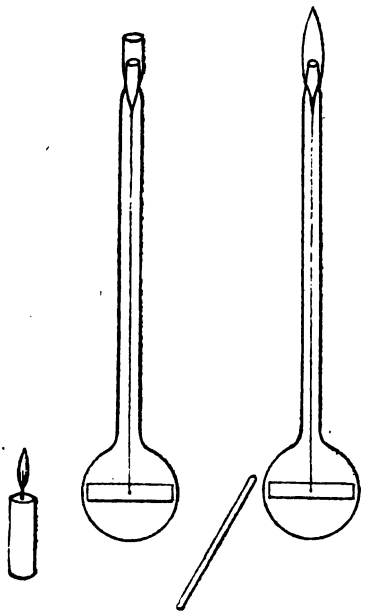
The simplest form of apparatus for showing this is given in Fig. 1. A bulb, *c*, 3 inches in diameter, is blown at the end of a glass tube, *a*, *b*, 18 inches long. In this bulb a fine glass stem

with a bar of pith, *d*, *e*, is suspended by means of a fibre of cocoon silk. When the apparatus is full of air at ordinary pressure, and radiation falls on one of the extremities of the bar of pith, a movement is obtained indicating attraction. If, however, the apparatus is exhausted by means of an improved form of the Sprengel vacuum pump, strong repulsion is shown when radiation is allowed to fall on one end of the index. Constructed with the proper precautions, and hermetically sealed off when the vacuum is perfect, this apparatus is so sensitive to heat that a touch with the finger on a part of the globe near one extremity of the pith will drive the index round over 90°, whilst it follows a piece of ice as a needle follows a magnet. With a large bulb very well exhausted, and containing a suspended bar of pith, a somewhat striking effect is produced when a lighted candle is placed about 2 inches from the globe. The pith bar commences to oscillate to and fro, the swing gradually increasing in amplitude until the dead centre is passed over, when several complete revolutions are made. The torsion of the suspending fibre now offers resistance to the revolutions, and the bar commences to turn in the opposite direction. This

movement is kept up with great energy and regularity as long as the candle burns.

The fact that attraction takes place when air is present in the bulb, and repulsion when air is

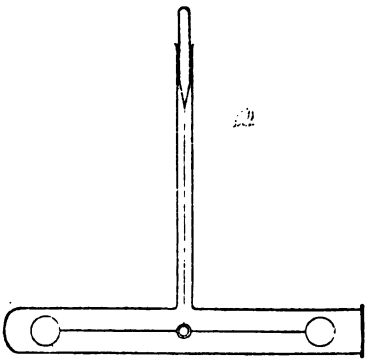
FIG. 2.



absent, is perhaps more strikingly demonstrated by Fig. 2. Two glass bulbs, each containing a bar of pith about 3 inches long and ½ an inch thick, are suspended horizontally by a long fibre

of cocoon silk. If a hot glass rod or a candle is brought towards the one containing air, the pith is gradually attracted, and will follow the candle or hot rod as it is moved round the bulb; but on bringing the candle or hot glass rod near the other bulb, the pith is strongly *repelled* by it. If, however, a piece of ice is placed near the pith bar which has just been repelled, the bar is attracted and follows the rod round, as a magnetic

FIG. 3.



needle follows a piece of iron. Neutrality, or no movement, is produced when the bulb is only partially exhausted; a minute trace of air interferes with the repulsion.

For his later experiments Mr. Crookes required a still more sensitive apparatus; he therefore

devised the form shown in Fig. 3, in which a fine glass beam, having discs of pith at each end, is suspended horizontally by a fine glass fibre, the whole being sealed up in glass and well exhausted. To the centre of oscillation a glass mirror is attached.

The advantage of using a glass fibre for suspending the beam is, that after each experiment it always returns accurately to zero. A thread of glass of less than a thousandth of an inch in thickness is wonderfully strong, of great stiffness, and of perfect elasticity, so that, however much it is twisted round short of the breaking-point, it untwists itself perfectly when liberated. Any desired amount of sensitiveness can, moreover, be obtained by drawing out the glass fibre sufficiently fine.

With this apparatus Mr. Crookes endeavoured to ascertain whether the movement of the bar of pith was due to light or heat, and to what portion of the solar spectrum was it most sensitive.

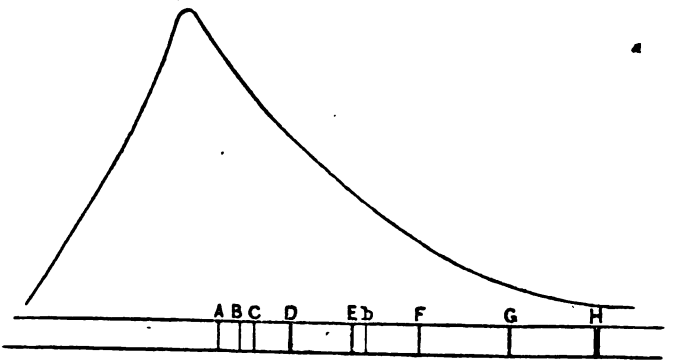
CHAPTER II.

THE CAUSE OF THE MOVEMENT OF THE BAR OF PITH.

WHETHER the movement is due to the effect of light or heat is a question difficult to determine, there being no physical difference between them. The spectrum, as scientific men understand it, extends from an unknown distance beyond the red to an indefinite distance beyond the violet. How far it would extend one way or the other if no absorbing media were present is not known. Fig. 4 is a diagram of the spectrum. The human eye is sensitive to a portion of the spectrum situated between the line A in the red to about the line H in the violet. But this is not a physical difference between the luminous and non-luminous parts of the spectrum; it is only a physiological difference. Now, the part at the red end of the spectrum

possesses, in the greatest degree, the property of causing the sensation of warmth, and of dilating the mercury in a thermometer, and of doing other things which are conveniently classed among the effects of *heat;* the centre part affects the eye, and is therefore called *light;* whilst the part at the other end of the spectrum has the greatest energy in producing *chemical action.* But it must

FIG. 4.



not be forgotten that any ray of the spectrum, from whatever part it is selected, will produce all these physical actions in more or less degree. A ray at the letter C, for instance, in the orange, if concentrated on the bulb of a thermometer, will cause the mercury to dilate, and thus

show the presence of *heat;* if concentrated on the hand we feel *warmth;* if thrown on the face of a thermo-pile it will produce a current of *electricity;* if thrown upon a sensitive photographic plate it will produce *chemical action;* and if thrown upon the instrument described in the last chapter it will produce *motion.* All these actions are inseparable attributes of the ray of that particular wave-length, and are not evidences of separate identities. That ray can no more be split up into five or six different rays, each having different properties, than the element iron, for instance, can be split up into other elements, one possessing the specific gravity of iron, another its magnetic properties, a third its chemical properties, a fourth its conducting power for heat, and so on. A ray of light of a definite refrangibility is one and indivisible, just as an element is, and these different properties of the ray are mere functions of that refrangibility, and are inseparable from it. Therefore if a ray in the ultra red pushes the instrument with a force of 100, and a ray in the most luminous part has a dynamic value of about half that, it must be understood that the latter action is not due to heat-rays which accompany the luminous rays, but that the action

is one purely due to the wave-length and the refrangibility of the ray employed. There is, then, no physical difference between heat and light, so, to avoid confusion, it is proposed to call the total bundle of rays which come from a candle or the sun, *radiation*.

It has been found, by throwing the pure rays of the spectrum one after the other upon this apparatus, that the actual rays which cause this action could be ascertained.

The apparatus was fitted up in a room specially devoted to it, and was protected on all sides, except where the rays of light had to pass, with cotton-wool and large bottles of water. A heliostat reflected a beam of sunlight in a constant direction, and it was received on an appropriate arrangement of slit, lenses, prisms, &c., for projecting a pure spectrum. Results were obtained in the months of July, August, and September; and they are given in the figure (Fig. 4) graphically as a curve, the maximum being in the ultra-red and the minimum in the ultra-violet. Taking the maximum at 100, the following are the mechanical values of the different colours of the spectrum :—

Ultra-red	100
Extreme red	85
Red	73
Orange	66
Yellow	57
Green	41
Blue	22
Indigo	8½
Violet	6
Ultra-violet	5

A comparison of these figures is a sufficient proof that the mechanical action of radiation is as much a function of the luminous rays as it is of the dark heat-rays.

CHAPTER III.

APPLICATION OF THE ACTION OF RADIATION TO PHOTOMETRY.

TO ascertain what influence the colour of the surface has on the action, Mr. Crookes constructed another torsion apparatus, in which six discs *in vacuo* could be exposed one after the other to a standard light. One disc always being lampblacked pith, the other discs could be changed so as to get comparisons of action. Calling the action of radiation from a candle on the lampblacked disc 100, the following are the proportions obtained:—

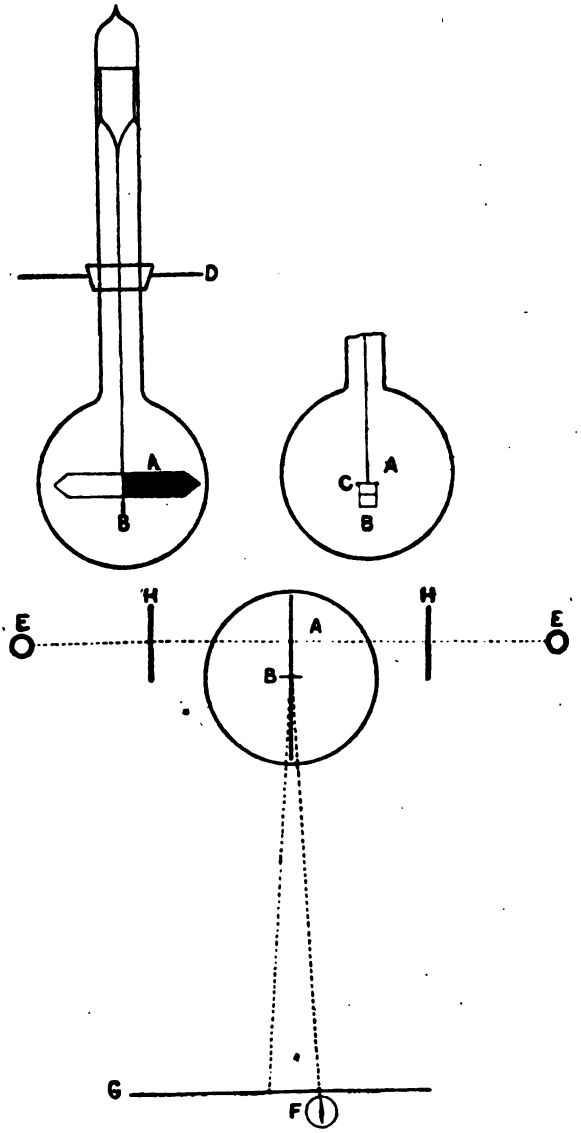
Lampblacked pith	100
Iodide of palladium	87·3
Precipitated silver	56
Amorphous phosphorus	40
Sulphate of baryta	37
Milk of sulphur	31
Red oxide of iron	28
Scarlet iodide of mercury and copper	22

Lampblacked silver	18
White pith	18
Carbonate of lead	13
Rock-salt	6·5
Glass	6·5

This table gives important information on many points: one more especially—the action of radiation on lampblacked pith—is 5½ times what it is on plain pith. A bar having one-half black and one-half white, exposed to a broad beam of radiation, will be pushed with 5½ times more strength on the black than on the white half, and if freely suspended will set at an angle greater or less according to the intensity of the radiation falling on it.

This suggested the employment of such a bar as a photometer, and the construction of an instrument on this principle is shown in Fig. 5. It consists of a flat bar of pith, A, half black and half white, suspended horizontally in a bulb by means of a long silk fibre. A reflecting mirror, B, and small magnet, C, are fastened to the pith, and a controlling magnet, D, is fastened outside, so that it can slip up and down the tube, and thus increase or diminish sensitiveness. The whole is completely exhausted and then enclosed in a box lined with black velvet, with apertures

Fig. 5.



for the rays of light to pass in and out. A ray of light from a lamp, F, reflected from the mirror, B, to a graduated scale, G, shows the movements of the pith bar.

Two candles, E E, are placed each 12 inches off the pith bar, one on each side of it. When the screens, H H, are removed, the candle on one side will give the pith a push in one direction, and the candle on the other side will give the pith a push in the opposite direction, and as they are the same distance off they will neutralise each other, and the spot of light will not move. When, however, one candle is cut off, the candle on the opposite side exerts its full influence, and the index flies to one end of the scale. Cut the other one off and obscure the first, and the spot of light flies to the other side. By balancing a standard candle on one side against any source of light on the other, the value of the latter in terms of a candle is readily shown.

In practical work on photometry it is often required to ascertain the value of gas. Gas is spoken of commercially as of so many candle-power. There are certain "standard" candles which are supposed to be made invariable by Act of Parliament. They never burn, however, with

the same luminosity from one hour to the other, and no two candles are alike. To surmount this difficulty place a "standard" candle at such a distance from the apparatus that it gives a deflection of 100 degrees on the scale. If it is poorer than the standard, bring it nearer; if better, put it farther off. Indeed any candle may be taken; and if it be placed at such a distance from the apparatus that it will give a uniform deflection, say of 100 divisions, the standard can be reproduced at any subsequent time; and the burning of the candle may be tested during the photometric experiments by taking the deflection it causes from time to time, and altering its distance, if needed, to keep the deflection at 100 divisions. The gas-light to be tested is placed at such a distance on the opposite side of the pith bar that it exactly balances the candle. Then, by squaring the distances, the exact proportion between the gas and the candle is obtained.

Before this instrument can be used as a photometer or light measurer, means must be taken to cut off from it all those rays coming from the candle or gas which are not actually luminous. A reference to the spectrum diagram (Fig. 4, p. 12) will show that at each end of the coloured rays

there is a large space inactive, as far as the eye is concerned, but active in respect to the production of motion—strongly so at the red end, less strong at the violet end. Before the instrument can be used to measure luminosity these rays must be cut off.

It has been found that a clear plate of alum, whilst letting all the light through, is almost, if not quite, opaque to the heating rays below the red. A solution of alum in water is almost as effective as a crystal of alum; if, therefore, there are placed in front of the instrument glass cells containing an aqueous solution of alum, the dark heat-rays are filtered off.

But the ultra-violet rays still pass through, and to cut these off a quantity of sulphate of quinine must be dissolved in the alum solution. This body has the property of cutting off the ultra-violet rays from a point between the lines G and H. A combination of alum and sulphate of quinine, therefore, limits the action to those rays which affect the human eye, and the instrument becomes a true photometer.

This instrument is very sensible to light. A candle 36 feet off produces a decided movement, and the motion of the index increases inversely

with the square of the distance, thus showing that the amount of action is in direct proportion to the amount of radiation.

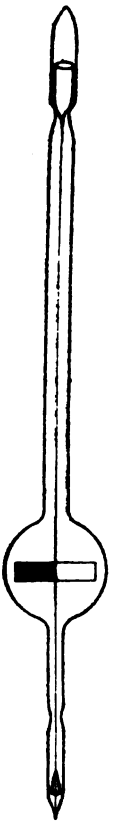
The experimental observations and the numbers which are required by the theoretical diminution of light with the square of the distance, are sufficiently close, as the following figures show :—

Candle	6	feet off	gives a deflection of	218·0°
,,	10	,,	,,	77·0°
,,	12	,,	,,	54·0°
,,	18	,,	,,	24·5°
,,	20	,,	,,	19·0°
,,	24	,,	,,	13·0°
,,	30	,,	,,	8·5°

The effect of two candles side by side is practically double, and of three candles three times that of one candle.

In the instrument just described the candle acts on a pith bar, one end of which is blacked on each side. But suppose the bar were to be blacked on alternate halves, and a light were placed near it sufficiently strong to drive the bar half round. The light will now shine on another black surface in the same position as the first, and the bar will be again driven in the same direction half round. This action will be again repeated,

FIG. 6.



the differential action of the light on the black and white surfaces will keep the bar moving, and the result will be rotation.

Such a pith bar, blacked on alternate sides, and suspended in an exhausted glass bulb, is shown in Fig. 6.

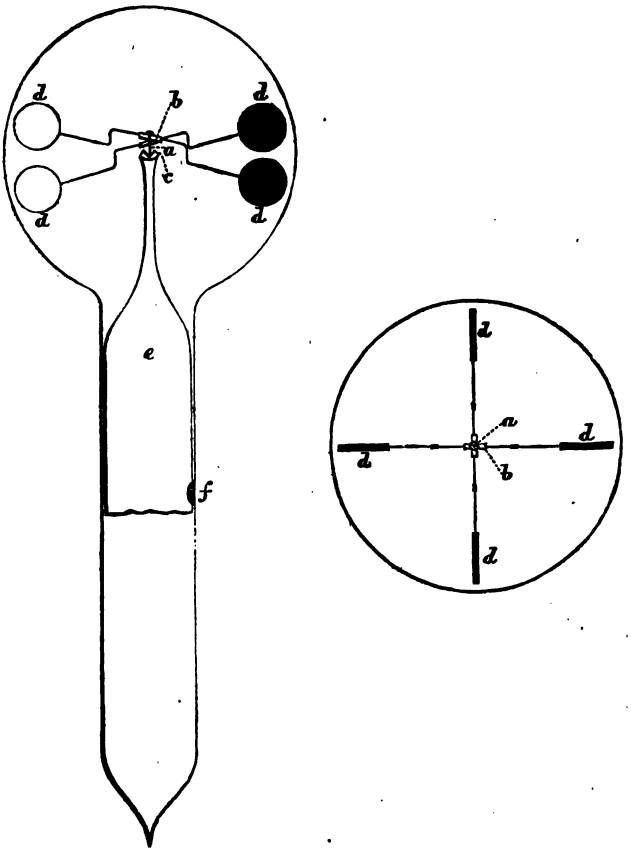
CHAPTER IV.

THE RADIOMETER.

FROM suspending the pith on a silk fibre, as shown in the last chapter, to balancing it on a point the transition is slight; the interfering action of torsion is thereby removed, and the instrument rotates continuously under the influence of radiation.

Taking advantage of this fact Mr. Crookes has constructed the Radiometer, shown in section and plan at Figs. 7 and 8. It consists of four arms, of some light material, suspended on a hard steel point resting in a cup, so that the arms are able to revolve horizontally upon the centre pivot, in the same manner as the arms of Dr. Robinson's anemometer revolve. To the extremity of each arm is fastened a thin disc of

FIGS. 7 and 8.



a. A very fine needle point.
b. Two pieces of straw.
c. Cup.
d d d d. Four mica or pith discs, blackened on one side. The arms between the straw in the centre and the discs are bent glass fibre.
e, Glass support holding cup.
f. Cement to keep the support *e* in its place.

roasted mica or pith, white on one side and lampblacked on the other, the black surfaces of all the discs facing the same way. The whole is enclosed in a thin glass globe, which is then exhausted to the highest attainable point and hermetically sealed.

The arms of this instrument rotate with more or less velocity under the action of radiation, the rapidity of revolution being directly proportional to the intensity of the incident rays. Placed in the sun or exposed to the light of burning magnesium, the rapidity is so great that the separate discs are lost in a circle of light. Exposed to a candle 20 inches off another instrument gave one revolution in 182 seconds; with the same candle placed at a distance of 10 inches off the result is one revolution in 45 seconds; and at 5 inches off one revolution was given in 11 seconds. Thus it is seen that the mechanical action of radiation is inversely proportional to the square of the distance. At the same distance 2 candles give exactly double, and 3 candles give three times, the velocity given by 1 candle, and so on up to 24 candles. A small Radiometer was found to revolve at the velocities shown in the following

table, when exposed to the radiation of a standard candle 5 inches off.

Time required for One Revolution.

Source of Radiation.	Time in Seconds.
1 candle, 5 inches off, behind green glass	40
" 5 " " blue "	38
" 5 " " purple "	28
" 5 " " orange "	26
" 5 " " yellow "	21
" 5 " " light red "	20

The position of the light in the horizontal plane of the instrument is of no consequence, provided the distance is not altered; thus two candles, 1 foot off, give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve.

In diffused daylight the velocity was one revolution in from 1·7 seconds to 2·3 seconds, according to the intensity of the incident rays. In full sunshine, at 10 A.M., it revolved once in 0·3 second, and at 2 P.M. once in 0·25 second.

When heat is cut off by allowing the radiation to pass through a thick plate of alum, the velocity

of rotation is somewhat slower, and when only dark heat is allowed to fall on the arms (as from a vessel of boiling water) no rotation whatever is produced.

CHAPTER V.

EXPERIMENTS WITH RADIOMETERS OF DIFFERENT CONSTRUCTION.

FOR experimental purposes the construction of the Radiometer may be varied to any desired extent. Several different kinds were exhibited by Mr. Crookes at the Soirée of the Royal Society, on April 5th, 1876; and as these instruments are now made by Mr. Hicks, a reference to their action will be included in this chapter.

A Radiometer with the vanes blacked on both sides shows rotation in either direction, according to the way the light falls on them. On a candle being brought near one side, the other side being shaded from the light, rapid rotation is produced, which is at once altered in direction by moving the shade to the other side. It is therefore

unnecessary, in order to produce rotation, for the surfaces of the discs to be differently coloured.

A Radiometer with six arms, and carrying a mirror in its centre, has been arranged to enable the movement to be shown by a beam of light reflected from the mirror to the ceiling. This may be used to show that coloured light does not interfere much with the movement. The placing of yellow glass in front scarcely diminishes it at all. Very deep coloured red glass diminishes it a little more. Blue and green glass make it go a little slower, but still do not diminish the speed one-half. If a screen of water is placed in front the instrument moves with diminished velocity, rotating with about one-fourth its original speed.

Taking the action produced by a candle flame as	100
Yellow glass reduces it to . . .	89
Red ,, ,, ,, . . .	71
Blue ,, ,, ,, . . .	56
Green ,, ,, ,, . . .	56
Water ,, ,, ,, . . .	26
Alum ,, ,, ,, . . .	15

If the candle is now moved a little distance off, so as to make the instrument move slower, and

a flask of boiling water is brought close to it, the luminous index no longer moves steadily, but in jerks. Each disc appears to come up to the boiling water with difficulty, and to hurry past it. More and more sluggishly do they move past, until one fails to get by, and the luminous beam, after oscillating to and fro a few times, comes to rest, and rotation will not recommence until the candle is brought to within a few inches of the glass globe. On pith radiometers the action of dark heat is to repel the black and white surfaces almost equally, and this repulsion is so energetic as to overcome the rotation caused by the candle, and to stop the instrument.

With a radiometer constructed of roasted mica, or of a good conductor of heat, such as metal, the action of dark heat is different. Apply a candle to one made of silvered copper, polished on one side and lamp-blacked on the other, and it moves slightly the normal way. Cover it with a glass shade heated so that it feels decidedly warm to the hand, and the rotation first stops, and then recommences the reverse way. On removing the hot shade the reverse movement ceases, and normal rotation recommences.

If, however, a hot glass shade is placed over a

pith radiometer the arms at once revolve the normal way, as if exposed to light. The diametrically opposite behaviour of a pith and a metal instrument when exposed to the dark heat radiated from a hot glass shade is very striking. The explanation of the action depends on the fact that the metal is one of the best conductors of heat, whilst pith is one of the worst.

If the metallic radiometer is heated strongly with a spirit-lamp, the arms spin round rapidly. When the whole bulb is hot remove the lamp: the rotation first diminishes, then stops, and then the instrument spins round just as fast the reverse way, but it is difficult to produce this reverse movement with a pith instrument. The action is due to the metal being a good conductor of heat. As it absorbs heat it moves one way; as it radiates heat it moves the opposite way.

If a Radiometer made of four pieces of looking-glass blacked on the silvered side, and the metal radiometer are placed side by side, and the light screened from them, they come almost to rest. If suddenly chilled by pouring a few drops of ether on each of the bulbs, both instruments begin to revolve; but whilst the movement in the case of the metal radiometer is direct, that

of the looking-glass instrument is reverse. And yet to a candle they both rotate the same way, the black being repelled.

With a Radiometer having inside it a platinum spiral the repulsion of the white and black surfaces is found to be equal when the spiral is below redness. Above a red-heat the black is repelled more than the white, and rotation takes place.

In the Turbine Radiometer the vanes are black on both sides, and are inclined at an angle like the sails of a windmill instead of being in a vertical plane. This instrument is not sensitive to horizontal radiation, but it moves readily, in one direction or other, according as the candle is held above or below.

The Heat Engine is also a Turbine Radiometer, having ice below and hot air above. It works by difference of temperature.

The experiment with a Radiometer showing rotation of the glass envelope when the vanes are held fixed in space are of great interest. The instrument is floated in a vessel of water, and four candles are placed round it so as to set the arms in rotation. The arms carry with them a magnet. A mark is put on the glass envelope so as to enable a slight movement of rotation to

be seen. A powerful magnet is now brought near the moving arms. They immediately stop, and at the same time the glass envelope commences to revolve in the opposite direction to that in which the arms have been revolving. The movement keeps up as long as the candles are burning, and the speed is about one revolution in two minutes. If the magnet is removed the arms obey the force of radiation from the candles, and revolve rapidly, whilst the glass envelope quickly comes to rest.

CHAPTER VI.

USEFUL APPLICATION OF RADIOMETERS.

THIS instrument has been too recently constructed to allow of more than a brief notice of the many uses for which it is applicable.

It has been already shown that by timing the revolutions of the instrument when exposed direct to a source of light—a candle, for instance—the total radiation is measured. If a screen of alum is now interposed, the influence of heat is almost entirely cut off, the velocity becomes proportionately less, and the instrument becomes a photometer. By its means photometry becomes much simplified; flames the most diverse may readily be compared between themselves or with other sources of light; a "standard candle" can now be defined as one which at x inches off causes the radiometer to perform y revolutions per minute,

the values of x and y having previously been determined by comparison with some ascertained standard; and the statement that a gas-light is equal to so many candles may, with more accuracy, be replaced by saying that it produces so many revolutions.

To photographers the radiometer will be invaluable. As it will revolve behind the orange-coloured glass used for admitting light into the so-called dark room, it is only necessary to place one of these instruments in the window to enable the operator to see whether the light entering his room is likely to injure the sensitive surfaces there exposed; thus, having ascertained by experience that his plates are fogged, or his paper injured, when the revolutions exceed, say, ten a minute, he will take care to draw down an extra blind when the revolutions approach that number. Still more useful will the radiometer be in the photographic gallery. Placing an instrument near the sitter at the commencement of the day's operations, it is found that, to obtain a good negative, the lens must be uncovered—not for a particular number of seconds—but during the time required for the radiometer to make, say, twenty revolutions. For the remainder of the

day, therefore, assuming his chemicals not to vary, the operator need not trouble himself about the variation of light; all he has to do is to watch the radiometer and expose for twenty revolutions, and his negatives will be of the same quality,* although at one time it may have taken five minutes, and at another not ten seconds, to perform the allotted number.

This instrument is also capable of giving much useful information in climatology. The temperature, the rainfall, the atmospheric pressure, the direction and force of the wind, are now carefully studied in most countries, in order to elucidate their sanitary condition, their animal and vegetable productions, and their agricultural capabilities. But one most important element, the amount of light received at any given place, has been hitherto but very crudely and approximately estimated, or rather guessed at. Yet it cannot be denied that sunlight has its effect upon life and health, vegetable, animal, and human, and that its relative amount at any place is hence a point of no small moment. The difficulty is now overcome by such an instrument as this. The

* In this brief sketch reference to the occasions in which the ultra-violet rays diminish in a greater proportion than the other rays is omitted.

radiometer may be permanently placed on some tall building, or high mountain, and, by connecting it by telegraphic wires to a central observatory, an exact account can be kept of the proportion of sunlight received in different latitudes, and at various heights above the sea-level. Furthermore, our records of the comparative temperature of different places have been hitherto deficient. The temperature of a country depends partly on the amount of rays which it receives direct from the sun, and partly on the atmospheric and oceanic currents, warm or cold, which sweep over or near it. The thermometer does not discriminate between these influences; but the radiometer will enable us now to distinguish how much of the annual temperature of a place is due to the direct influence of the sun alone, and how much to the other factors above referred to.

At first these instruments were made of the very lightest material possible, some of them not weighing more than half a grain; and where extreme sensitiveness is required lightness is essential. But the force which carries them round is quite strong enough to move a much greater weight, and having ascertained this fact

another useful application suggested itself. Fig. 9 shows an instrument carrying a magnet, and outside is a smaller magnet, delicately balanced in a vertical position, having the south pole at the top and the north pole at the bottom. As the inside magnet comes round, the outside magnet, being delicately suspended on its centre, bows backwards and forwards, and, making contact at the bottom, carries an electric current from a battery to a Morse instrument. A ribbon of paper is drawn through the "Morse" by clockwork, and at each contact—at each revolution of the radiometer—a record is printed on the strip of paper by dots; close together if the radiometer revolves quickly, farther apart if it goes slower.

The inner magnet is generally too strong to allow the radiometer to start with a faint light without some initial impetus. Imagine the instrument to be on the top of a mountain away from everybody, and that it is necessary to start it in the morning. Outside the bulb are a few coils of insulated copper wire, and by depressing the key for an instant an electric current from the battery is passed through them. The interior magnet is immediately deflected from its north-south posi-

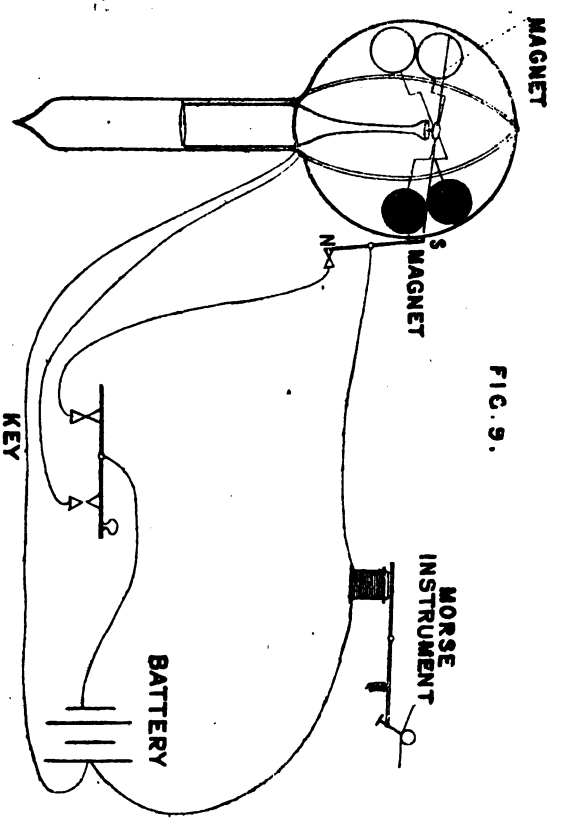
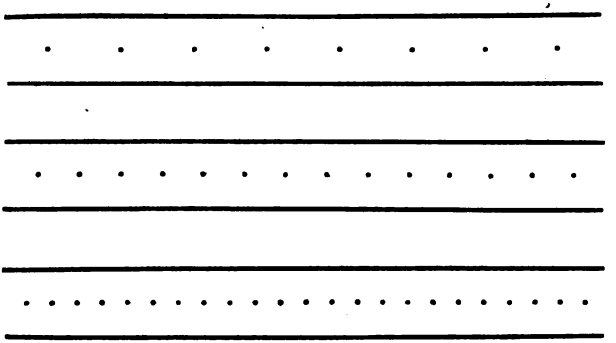


FIG. 9.

tion, and the impetus thus gained enables the light to keep up the rotation. In a proper meteorological instrument there should be an astatic combination inside the bulb, so that a very faint light would be sufficient to start it, but for a simple experiment it may be set going by an electric current; place a candle near the mag-

FIG. 10.



netic radiometer, then touch the key; the instrument immediately responds; the paper unwinds from the Morse instrument, and on it will be found dots in regular order. Put the candle 8 inches off, and the dots come wide apart. Place it $5\frac{3}{4}$ inches off, and two dots come where one did before. Bring the candle 4 inches from

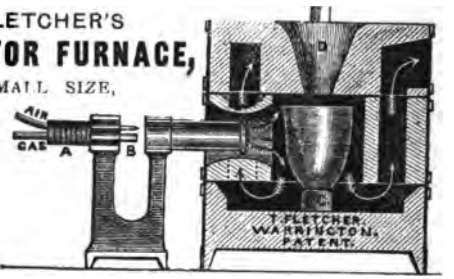
the instrument, and the dots become four times as numerous (Fig. 10), thus recording automatically the intensity of the light falling on the instrument, and proving that in this case also the radiometer obeys the law of inverse squares.

London: Printed by E. J. Davey, Boy Court, Ludgate Hill, E.C.

FLETCHER'S

INJECTOR FURNACE,

SMALL SIZE,



WILL MELT HALF A POUND OF CAST-IRON IN EIGHT MINUTES, USING LESS THAN SEVEN CUBIC FEET OF ORDINARY GAS AND STARTING WITH THE FURNACE COLD. The loss of heat by radiation is *nil*, the outer casing remaining absolutely cold. Its power is limited only by the capability of resistance to fusion of the refractory casing. Half a pound of steel can be melted and poured in less than twenty minutes. It is absolutely secure against loss by boiling over or cracking of a crucible in the melting of valuable metals, &c., and turns out sounder and tougher ingots of gold, silver, &c., than any known furnace.

Hot-Blast and other Blowpipes, Special Gas Furnaces with and without blast for Spectroscope Analysis, Cupelling, Enamels, Roasting Ores, &c. Burners and Blowpipes for all temperatures from that of a drying closet to the fusion of platinum. Foot-blowers giving any required pressure of air with perfect steadiness up to 4 lbs. on the square inch. Special designs to order without extra charge. Detailed list with engravings on application to THOS. FLETCHER, F.C.S., MUSEUM STREET, WARRINGTON, Manufacturer of Platinum Alloys, Oxychloride of Zinc, &c., for Dentists. (*See Loan Collection of Scientific Apparatus, South Kensington, Section* 8.

THE QUARTERLY JOURNAL OF SCIENCE,

AND

ANNALS OF MINING, METALLURGY, ENGINEERING, INDUSTRIAL ARTS, MANUFACTURES, AND TECHNOLOGY.

Edited by WILLIAM CROOKES, F.R.S., &c.

Published on the 1st of January, April, July, and October, price 5s.

This Journal offers to the reading public information in the highest paths of Scientific Research, and is also a medium of communication between Students in the various branches of Physical Science.

In addition to Original Articles by eminent investigators, and Reviews of Books, &c., the Journal contains under the heading Progress in Science a *resumé* of the labours of both English and Foreign Scientific men.

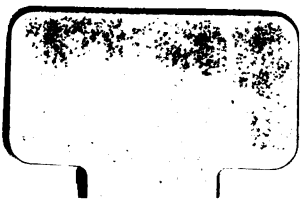
LONDON: 3, HORSE-SHOE COURT, LUDGATE HILL, E.C.

THE CHEMICAL NEWS

AND

JOURNAL OF PHYSICAL SCIENCE.

Edited by WILLIAM CROOKES, F.R.S., &c.

Published every Friday. Price 4d. Annual Subscription, post free, including copious Indices to the two half-yearly volumes, £1.

LONDON: BOY COURT, LUDGATE HILL, E.C.